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ABSTRACT

An input output model for individualizing learning in computer-assisted instruction (CAI) is analyzed, specifying a stimulus array, cognitive processes, and response requirements. These three components are discussed as keys to both instructional and curricular development processes; the appropriate use and control of instructional strategies are considered in relation to the three components. Next, a description of a systems model for CAI curriculum development (including a discussion of problem identification, task analysis, entry behaviors, behavioral objectives, instructional strategies, media assignment, and field tests and studies) and a description of the staff roles (including content scholars, behavioral scientists, physics writers, CAI coders, media specialists, computer operators, computer systems programers, data analysis programers, CAI proctors, and graduate students) which developed from a physics CAI project at Florida State University comprise the major portion of this report. Also included are a brief description of data analysis and management techniques and a summary which isolates eight factors important in determining the rate of development and success of a computer-based curriculum project. (SP)

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CAI CENTER

TECH MEMO

DEVELOPMENT PROCESSES IN CAI PROBLEMS,

TECHNIQUES, AND IMPLICATIONS

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ABSTRACT

Development Processes in CAI Problems,
Techniques, and Implications

The nature of developmental processes within CAI is introduced by a consideration of a learning model for adaptive instruction. The distinction between instructional processes and curriculum developmental processes are elaborated in terms of instructional strategies. The nature of the instructional strategies as well as a "systems approach" model for CAI curriculum development are documented by the empirical experience at Florida State University. Ten significant professional roles required for a multi-media CAI curriculum developmental project are presented. The paper concludes with summary propositions concerning the problems and their solutions in curriculum development within the CAI world.

DEVELOPMENT PROCESSES IN CAI PROBLEMS, TECHNIQUES, AND IMPLICATIONS[1]

Duncan N. Hansen

INTRODUCTION. Computer-Assisted Instruction (CAI) is now more than a decade old. Having moved from a conceptual ideal, CAI has both proven its operational feasibility and revealed all of the complexities of the educational world. Moreover, it has confronted the educator with the diverse requirements of a technological approach to instruction. Thus, the field of CAI has by necessity addressed itself both to models of the learning process as well as to issues dealing with efficient techniques for curriculum development within the requirements of available computer technology.

For the purposes of this paper, a brief introduction to a learning model for adaptive instruction will be presented in order to clarify the difference between the instructional process and the curriculum development process. In turn, more specific remarks will be made in regards to instructional strategies as these form the primary intersection between these two theoretical and empirical domains. And finally, the major portion of the paper will describe our experiences at Florida State University in developing an autonomous multi-media computer-based collegiate physics course. In this final section, a "systems approach" model to CAI curriculum development will be presented. In order to effectively evolve and utilize the systems model in the development of

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[1]Paper presented at Computer-Based Learning Seminar at The University of Leeds, England. (September 8-12, 1969)

the FSU physics course, ten significant professional roles in multi-media CAI curriculum developments will be described. The paper will then conclude with a set of summary propositions concerning the area of curriculum development within the CAI world.

INSTRUCTIONAL LEARNING MODEL. For the purposes of clarification, it is important when developing CAI materials to have some conception about the learning process being utilized by the student. Moreover, as has been redundantly asserted, CAI is justified by its individualization of the learning process. In conceiving of the individualization of the learning process, most educators have tended to define the process as one of supplying appropriate instruction to satisfy the student's needs. This assertion is ambiguous at best. For example, are the needs to be defined in terms of the student's frame of reference, especially in terms of his wants? Or is it to be defined in terms of some benevolent power who controls what the student should have? The concept of needs is an internal behavioral construct evolving out of research within human motivation. The problem of its definition can be witnessed within the literature of human motivation and personalities process. As an alternative theoretical approach, one can specify a simple input/output model for the student and utilize this model to consider some of the preliminary factors in CAI curriculum development.

Turning now to this simplified model, individualization of learning can be thought of as a process by which the student maximizes his informational input, mental processing, memory storage, and

response output. In psychological terms, this conception of learning behaviors specifies the stimulus array, the cognitive processes, and the response requirements. Breaking the behavioral processes of learning into these three components will bring into focus some of the potential CAI curriculum development factors to be discussed in a later section of this paper.

In regards to stimulus input, investigators such as Briggs and Gagné assert that greater learning gains can be achieved by appropriate assignment of instructional media. Matching appropriate films, audio lectures, or printed material to individual characteristics should, it is claimed, lead to better learning results. Current work in the area of Individualized Prescribed Instruction (IPI) and our own experience with CAI indicate that the assignment of appropriate media within CAI is a highly complex problem. For example, there are research findings indicating that cathode-ray tube presentations to low ability students may in fact deter the learning process, or that audio lectures in some cases prove superior to film presentation, even though there is an obvious reversal in terms of information characteristics of the two media. As a consideration within a CAI research project, it is therefore important to prepare a design which allows for an assessment of the various media being utilized. As a feature in the adaptive nature of a CAI curriculum, alternative media approaches will ultimately provide useful insight as to range and optimality of each in a given curriculum.

In regards to internal processes, the middle component in this simplistic model, the manipulation of the level of difficulty of the

learning materials has proven to be a powerful variable. In research at Stanford University, as well as at a host of other CAI Centers in the United States, it is clear that optimal matching of the level of difficulty of the learning materials to the student's performance level leads to improved mental processing as well as enhanced long term retention. As an example, a recent study in our laboratory indicated that the use of concurrent memory retention indices provide enhanced learning in comparison with more general individual difference variables such as an IQ score. While a large array of alternative psychological models can be proposed for this internal processing by the student, it is important to consider within CAI curriculum development such simplistic factors as the scaled information load as evidenced by a readibility indices, the complexity and sequential structure of solution algorithms, and finally the fostering of long-term retention.

Turning now to the response side, the third component in the model, it would seem that most CAI curriculum development projects have constrained themselves by the availability of computer/terminal equipment. Encouragingly, though, most students indicated a quick adaptation to the response requirements of the student/computer interface with little or no detrimental effects from one alternative device as opposed to another. To be more specific, very young students have clearly demonstrated the ability to master the typewriter keyboard, or no evidence exists as to the superiority of an electronic blackboard as opposed to a more inexpensive keyboard device. As a wider array of curriculum materials are developed, it may become clear that more appropriate matching of response characteristics of student/computer interface may foster more optimal learning.

CAI curriculum projects may desire to be more exploratory in the area of alternative response devices.

While acknowledging that this input/output model for individualized learning is extremely simple, it provides a CAI curriculum project with the essential considerations in thinking through each specific stage in the curriculum developmental process. A failure to consider the student and his related behavioral processes has been one of the major flaws in many of the CAI developments to date in the United States. It is also important to indicate that there has been little experimental investigation in regard to appropriate matching of learning, computer, and curriculum characteristics. Until this void is eliminated, major CAI curriculum developments will be limited in regard to their implementation and implications.

INSTRUCTIONAL STRATEGIES. The major intersection of a model of the learning process with that of a CAI development model comes under the rubric of instructional strategies. This term was first referred to by Stolurow in terms of the logic flow of the instruction, that is, the branching structure utilized within the context of correcting error responses or applying remedial procedures. As a contrasting conceptual frame of reference Smallwood proposed a quantitative model by which to define instructional strategies that lead to optimal solutions for the learning outcome. From my point of view an instructional strategy is one that allows for selection from the alternative plans of instruction the one that hopefully will lead to an optimal performance level. These instructional plans involve the characteristic of the learner, the structure of the curriculum material being developed, the behavioral processes being utilized by the

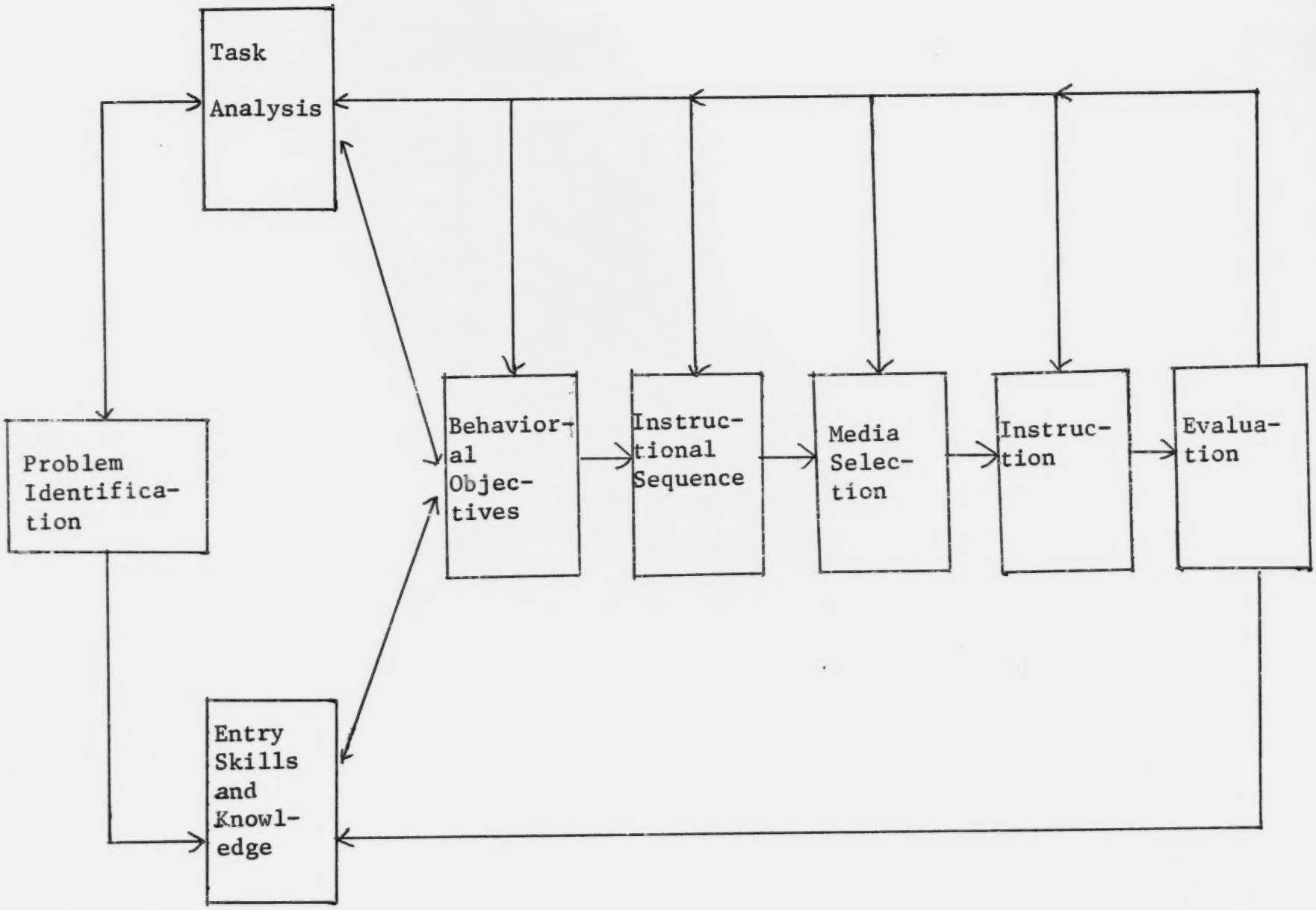
student, as well as the student's coping behavior that results in maximizing his rewards and minimizing his efforts. Thus the student, from my point of view, will always try to maximize his rewards and minimize his efforts in terms of either playing an "interesting game" or contending with the problems posed by an educational system.

The primary issue concerns who selects and controls the instructional strategy. At one end of the continuums Stolurow, Smallwood, and Atkinson would suggest that we prescribe the optimal selection of learning events for the student. They claim that having once understood the student's basic behavioral processes that we, as an outside decision-making mechanism, can best decide his prescription for instruction. At the other end of the continuum, Grubbs has suggested that a student, given his better self-awareness of all of his internal mental processes and immediate state of understanding, can best select his own strategy for acquiring a set of complex concepts. For my part the process for the selection of instructional strategies should be considered one of negotiation between the instructional system be this a teacher or a computer and the student. This negotiation should allow for more student initiative and self-selection given better desire performance, that is, the better the performance by the student the more we offer him self-selection among the learning topics, alternative media, and criterion levels of performance. Recent work in the area of social learning contingency games indicate that allowing for student initiative leads to at least these two results: (1) more student accomplishment of the desired performance defined in terms of behavioral objectives in less time, and (2) more motivation by the students to move towards the category of superior performance. Thus CAI curriculum projects must constantly consider the social learning contingencies if a successful

overall instructional course is to be developed. The frame by frame issues typically discussed within programmed instruction appear to be marginal in their impact on CAI learning. In essence I am recommending that a wider and richer approach to instructional strategies with more student involvement will provide better payoffs in learning. We turn now to the specific issues in CAI curriculum development.

SYSTEMS MODEL FOR CAI CURRICULUM DEVELOPMENT. The systems approach has evolved as a set of ideal analysis and implementation procedures that can be followed in order to develop effective learning materials which in turn maximize the conceptual development of the students. The essential features of the system model are schematically presented in Figure 1. The first step in the process is the exploration and description of the instructional problems plus associated context constraints of the instructional setting. Concurrently, a task analysis of the conceptual requirements, as well as the behavioral processes, should be performed. A thorough assessment of the entry skills and prior knowledge of the student population for which the course is intended is also required. These sub-analyses then culminate in the course behavioral objectives which form a description of the criterion performances which are desired as outcomes for the student. In turn, the behavioral objectives are sequenced and structured into instructional strategies for given segments within the course. As a consequence, appropriate selection of media and instructional contexts provides the implementation prior to the first field test. The empirical results obtained in the field test provide the basis for evaluation and subsequent revision cycles.

Systems Development Model



While this is an overly simplified representation of the process, each of the system's components will be described in more detail below. The adaptation and utilization of this model by the FSU project staff will be emphasized.

1. Problem Identification. In the process of identifying the existing instructional problems within the physics course, it was found useful to employ a number of techniques by which to reveal specific problems upon which the CAI approach could focus. If conceptual learning problems can be identified in terms of behavioral phenomena such as prior test scores or responses on homework assignments, etc., a CAI project will be much further ahead in its formularization of appropriate behavioral objectives.

Four techniques were utilized to identify problem areas within the physics course. First, a thorough literature search of the physics education area provided information about the needs of students for prerequisite quantitative abilities, for high order abstracting and concept formation abilities, and for sophisticated problem-solving skills. In the last analysis, it was apparent that one learns physics to the degree that one can solve physics problems. This primary behavioral focus on problem solving for physics courses should not be minimized.

The second technique involved a number of conferences between members of the FSU physics faculty and the project staff in order to gain case study information about learning problems revealed during class discussion periods as well as faculty office hours. These conferences pointed up the need for good conceptual development and associated problem-solving skills plus the deficiency of student motivation for certain

aspects of the course. These motivational factors seem to determine class attendance, work effort, and general intellectual commitment.

In terms of the third technique, all of the prior test results over the previous three-year period provided a clear indication that the later portions of the course, namely electromagnetic phenomena and atomic physics, provided the greatest difficulty for the students in terms of items failed on final examinations.

The fourth technique for identifying difficult concept topics leads to a set of CAI physics problems which were presented on four different occasions to samples of students enrolled in the conventional physics course. The performance of the students on these CAI instructional problems provided performance data upon which all future comparisons for revision and improvement purposes were based. The availability of baseline data is an extremely useful technique and should not be minimized.

All of these efforts clearly indicated that throughout the physics course there were specific learning or conceptual problems that influenced the overa[illegible] performance into a gradual decline as the students proceeded through the course.

2. Task Analysis. A task analysis of the curriculum concepts to be taught to the students provided an overall structure of the course content in a manner that delineates the relationship among topics in both sequential and hierarchical fashion. In terms of introductory physics, the integrating conception of particle and wave phenomena provides a recurrent and increasingly complex set of theoretical propositions as the student moves through the topics on measurement, optics, mechanics, electromagnetism, and modern physics. This relatively stable conceptual

structure has evolved over a long period of time and is easily inferred from a review of existing textbooks.

For the purposes of the project, the task analysis of the content was performed in two ways. First, a video recording was made of the twenty-nine conventional classroom lectures and demonstrations. These video tapes provided an opportunity to study both the detailed presentations of concepts, but more importantly to identify the language and representatives utilized in the conventional setting. Parenthetically, it is highly recommended that video recordings of a professor who is highly successful in conventional teaching provides many important insights into the pedagogical techniques and language appropriate for instruction in a given course area. Moreover, the video recordings allow one to identify the characteristics of concept presentations which will be of value when consideration is given to media assignment. And, lastly, it provides an invaluable tool by which the professor can compare and reconsider the sequencing of portions of the course.

As a second task analysis technique, four currently popular physics textbooks were analyzed. Interestingly enough, the topic sequence in all of these textbooks was exactly equivalent; that is, the authors employed the concepts of particle and wave phenomena in order to integrate the topics within the introductory physics course. As an additional benefit, the analysis of the homework problems required at the end of each chapter indicated many of the behavioral requirements currently considered important in introductory physics.

3. Entry Behaviors. An empirical assessment of the skills and performance level of the student population as they enter a course is an absolute prerequisite for the preparation of optimal learning materials.

These performance levels are commonly referred to as entry behaviors. Entry behaviors represent a characterization of the heterogeneity of both cognitive and affective processes and prior knowledge levels on the part of the students. Obviously, as gaps or deficiencies are revealed, these impinge directly on the conceptual attainment as represented in the task analysis. In essence, entry behavior should indicate both the aptitudes and abilities of the students at the beginning of the course and the appropriate entry points into the conceptual flow identified within the tasks analysis of the course.

The entry behaviors of the FSU students were assessed in terms of scores on the Florida Collegiate Entrance Examination, performance on midterm and final examinations in the conventional physics course, and most importantly the performance on the CAI problem sets. These CAI problem sets were a fair representation of each of the sub-concepts presented in the conventional setting. The students typically came to the CAI Center prior to each examination for one to two hours of instructional interaction. Each CAI item poses a physics problem; if the student could not answer it, help was provided until a successful answer was emitted. The preparation of this type of CAI complementary problem set is highly recommended in order to specifically identify the performance level of students both prior to and during a conventional course preparation.

Problem sets have great merit in that they save a great deal of time and energy in terms of preparing desired remedial materials and delimiting professors' and authors' intuitions about potential learning problems. The area of CAI curriculum development has been fraught with extensive remedial material preparation which is rarely used by any of the targeted students. It was discovered that utilizing the CAI homework

problem results saved considerable time and focused the preparation of learning materials specifically on difficulties demonstrated by concurrently enrolled students. Thus empirical techniques provide an efficient approach to specifying student entry behaviors.

4. Behavioral Objectives. Information from the course analysis, task anlaysis, and entry performance levels was utilized in formulating the behavioral objectives of the CAI physics course. Since a direct comparison with the conventional course was desired, the concepts and related behavioral objectives were arbitrarily divided into twenty-nine segments referred to as lessons. These closely parallel the presentations in the conventional lecture-demonstration course. The behavioral objectives were treated as hypothesized propositions which could be and ought to be achieved by the students given an effective instructional treatment.

For each lesson the behavioral objectives were broken down in terms of prerequisite skills and concepts plus the behavioral objectives for that given instructional segment. It was observed in the process of stating the behavioral objectives that the availability of prior test items as well as the video recordings of the conventional class presentations proved an invaluable data source from which to formulate precise performance related statements. These precise behavioral objectives assist one in the next step, namely, forming insturctional strategies.

5. Instructional Strategies. Since the conceptual structure of the collegiate physics course did not pose major sequencing problems because of the constancies within existing textbooks as well as the equivalent structure or reverification from the CAI task analysis, the instructional strategies focused on the conveyance of appropriate learning

expectancies to the students via various types of media presentations. Distinctive instructional strategies were utilized for each of the subsections of a lesson.

First, each textbook reading assignment was followed by a detailed CAI quiz which had a specified criterion performance level. If a student failed to meet criterion, he was given a remedial reading assignment and recycled through the quiz items. This strategy insured that the students' comprehension of the text was more than sufficient. In regard to the audio lectures, a set of typed notes and diagrams were utilized in conjunction with the audio tapes. The concepts presented in the audio lectures again were evaluated in terms of CAI quizzes. For remedial purposes, students were required to repeat the presentation if their performance did not meet criterion. For both the physics conceptual film presentations and the laboratory film loop presentations, there were related CAI quiz items. Again, students were directed to return to the presentation if their performance was not at or above the desired criterion level.

In each of the lessons, the final assessment of the behavioral objectives was in terms of a CAI problem set. Students were provided detailed remediation within the structure of each of the problems. As a follow-up, a parallel form of the physics problems was presented as review material prior to both the midterm and final examinations. These CAI review problems again assessed the long-term retention of the behavioral objectives for each of the lessons.

In essence, the instructional strategies were created in order to relate hypothesized sets of psychological states through which the student would pass while completing various tasks in each of the

physics lessons. In this regard, the students were provided a recognition of the learning expectancies to be covered within each of the sub-sections of the physics course. This was accomplished via explicit directions plus criterion quizzes at the end of each sub-section. These psychological expectancies provided involvement and commitment on the part of the student to obtain the desired behavioral objectives. Without this psychological commitment, there would be a low probability that the CAI instruction would produce the desired optimal learning outcomes.

Having gained the student's involvement, the new information of each lesson must be sequenced in light of the prior knowledge and problem-solving skills gained in prior lessons by the student. The algorithms of these problem-solving skills are clearly related to the specific sub-concepts of each topic in the physics course. For example, the solution of kinetic energy problems related back to considerations of the sub-concepts of force and matter. If a student had mastered the sub-component elements of each concept, then the more complex algorithms could be applied.

As a last feature of the instructional strategy, an attempt was made to provide frequent conceptual closure and the self-realization by the student of having gained competency over each specific topic in the course. This psychological requirement for frequent closure is one of the most overlooked aspects involved in effective instructional strategies.

6. Media Assignment. As a related aspect of the development of the automated physics course, the process of assigning appropriate media for each concept is critical. Most of these decisions are typically based on relatively unexplored research conceptions. Obviously, the

media utilized for a given presentation has to be as contiguous or as similar to the response modality as possible. The physics course utilized a wide variety of multi-media modalities. Rather than restricting the presentation only to the CAI-CRT terminal device, the most appropriate match between the media and the information features of the concepts was attempted. This use of multi-media within the physics course offered an opportunity to analyze the learning impact of these media types.

The following guidelines were used for media selection. First, when attempting to facilitate acquisiton of conceptual material, the use of multiple sensory channel inputs was maximized. For example, in presenting a complex demonstration of physical phenomena like kinetic energy, either PSSC films or film loops were used in order to maximize the richness of the sensory characteristics. Second, when allowing for both acquisition and intellectual problem solving, the information source was focused within restricted sensory channels. For example, many problem-sovling routines were illustrated within the audio lecture through the use of accompanying graphic presentations. Third, when attempting to build problem-solving skills for long-term retention, the use of feedback and correction via CAI was maximized. The interactive feature of the CAI system was utilized in order to individualize the feedback, the correction, and to insure sufficient practice. Fourth, when faced with evaluative decision-making, especially in determining successful attainment of the behavioral objectives, the real-time student history feature of the CAI system was utilized in order to scan over a number of learning tasks in determining an appropriate decision about criterion performance. And lastly, the logistics of the instruction from the

student's point of view in moving from one media device to another was considered. While interruptions may break the monotony of the instructional process, it has been found that interruptions within learning processes can interfere with acquisition and retention. Thus, an attempt was made to match appropriate media in order to have a smooth flow through a given lesson.

7. Field Tests. In conducting the field tests and subsequent revisions, the following factors seemed important based upon our experiences. First, appropriate selection of students who vary according to aptitude, prior knowledge, and other psychological characteristics is difficult to obtain but important. The forming of special sub-groups to assess their reaction to the materials formed the substance of all future revisions in the CAI physics course. Secondly, the importance of looking at learning frame statistics as well as overall course performance became quite contingent upon our ability to process and analyze the CAI data encoded within the computer system. As will be explained in a subsequent section, a computer data analysis and management system was developed in order to perform these analyses. Various reports proved invaluable to the course authors in the revision process and should be considered an essential part of any computer approach to instruction. Third, good interview techniques should be employed constantly, not just at the end of the course, but throughout the instructional process. Informal comments from students can be treated as hypotheses which need to be checked out as to their validity and potential implications for course change. The informal comments from students concerning scheduling and the reliability of various media devices indirectly formed the basis upon which certain equipment and scheduling changes were made in the CAI

physics course. Lastly, a pool of experienced personnel with clear understanding of their functions is required when one is pursuing development work in computer approaches to instruction. For example, the primary function performed by the student proctors was one of assistance to the students, but more importantly they served as input sources by which important information was gained both through direct observation of and interactions with the students.

8. Field Study and Project Development Schedule. Table 1 (see next page) presents a brief quarter by quarter description of the primary project activities. It can be observed that most of the first year was devoted to developing the course. The first field study was conducted in the fall of 1967. The second field study, the most complete of the experimental versions, was presented in 1968. The final field study that focused on individual difference outcomes was completed by December, 1968. This project schedule offers at least one example of the time requirements to develop a collegiate CAI course.

Table 1

Developmental Schedule for the Project

	First Year, (1966-7)	Second Year, (1967-8)	Third Year, (1968-9)
Fall	Project Initiation Staffing, CAI Problem Exercises, Course Analysis	First Course Field Test, CAI Problem Exercises	FLEX Field Test
Winter	Video Recording, (1967), CAI Problem Exercises, Task Analyses Entry Behaviors	Data Analysis, (1968) Course Revision	Data Analysis, (1969) Final Report, Project Ended
Spring	CAI Problem Exercises, Behavioral Objectives, Film Preparation, Course Authoring	Second Course Field Test CAI Problem Exercises	
Summer	CAI Coding, Audio Loop Preprations, Graphics Preparation, CAI Problem Exercises	Data Analysis, Course Revision	

Management Techniques. The primary task in the management of the project consisted of evolving and redefining the functional roles for staff personnel. As new needs and related functions were identified, a staff member assumed the responsibility and in essence created the role. The primary mechanism for planning and coordinating was a weekly staff meeting. While more formal project planning techniques like PERT might have improved the project's development, the unknown nature of the CAI course development process resulted in the use of more informal

planning and communication techniques. However, the use of the Systems Approach as a model for CAI curriculum development guided our efforts.

Any CAI project utilizing a rich array of technological equipment requires a complex functional organization that differentiates roles and related competencies. This section of the paper describes the various roles which evolved within the physics project.

1. Content Scholars. Foremost within a CAI project is the requirement for excellent subject matter scholars who have complete command of the concepts to be taught. The project was fortunate to have the involvement and professional commitment of four professors from the Florida State Department of Physics. While the project did not create a major new sequencing of the concepts of physics, each of these men provided excellent insights within the following phased steps.

First and foremost, these professors devoted innumerable hours to the preparation of a detailed conceptual outline of the course. In addition, they allowed us to video-record their classroom presentations over two successive quarters. These video recordings were used to study the language and demonstrations utilized in these lecture presentations. As various segments within the CAI course were developed, each of the four professors provided valuable contributions in terms of critiquing and editing the course materials. Since these materials were automated, these professors went through them in a student mode in order to detect any misconceptions or inaccuracies. In addition, the professors provided invaluable service in the continual preparation of new sets of midterm and final examination questions as well as the homework assignments for the physics class. It should be noted that a common set of examinations

and homework problems was utilized in comparisons between the conventional and CAI versions of the course.

Informally, these physics professors also contributed to the development of the field studies by lending professional support to the process of gaining permission to teach the CAI version for full university credit. While this may seem like a minor point, one should not minimize the time and energy required to gain permission to offer credit for an experimental instructional course. Typically, the university administrators wish the assurance that the "new" course will be equivalent to or better then the existing course. Prior to the first field study, as many arguments as possible for accrediting the course were assembled with the knowledge that the empirical outcomes might in fact refute some of the claims.

2. Behavioral Scientist. An equivalently important talent is represented by the behavioral scientists who provided insights into the overall creation and implementation of the systems approach. Being "behavioral methodologists," the behavioral scientists provided reasonable criteria for the behavioral consequences of the instruction. They also analyzed the issues dealing with the topics of entry behaviors, task analysis, behavioral objectives, and instructional strategies. Concurrently, the behavioral scientists contributed the major structure of the research design as well as specific hypotheses which are reported within the field studies. Since they had prior experience with experimental data analysis, the responsibility for analyzing the instructional outcomes and interpreting them also was assumed by the behavioral scientists. Perhaps most importantly the behavioral scientists provided

the managerial leadership and the training of other personnel within the project in order to achieve the project goals.

3. Physics Writers. Since the talents of both the professional physicist and behavioral scientists are in exceedingly short supply the project recruited a full-time physics writer. After being trained in the nature of CAI and the desired instructional strategies, plus viewing the video tapes for appropriate language, the full-time writer, as well as three part-time physics graduate students, proceeded ahead with the detailed writing of the instructional materials. Thorough command of the physics content and an understanding of the overall systems approach and computer capabilities were required. The majority of the writing was performed by these authors. It can be recommended that such full-time writers form an essential ingredient in a reasonably large CAI developmental project.

4. CAI Coders. After the instructional material has been edited, a CAI coder entered it into the FSU-IBM 1500 CAI system. The CAI coder had a thorough understanding of the Coursewriter II language, the uses of switches and counters for real-time data analysis, and the role of macros which provide a method for more quickly encoding curriculum materials. The CAI coders, who are excellent typists, typically performed both the entry and copy editing functions; that is, many minor mistakes were picked up by these coders and referred back to the physics writers and the physicists. This type of informal editing can be exceedingly important within the implementation phase of CAI.

5. Media Specialists. In terms of the physics project, parttime media specialists were employed who helped in the preparation of the concept films as well as the audio tapes. Since a random access audio

system was avilable for this project, instruction in the preparation of tapes was required. While no special or unique functions evolved for these media specialists, they did prepare all of the final version of the curriculum.

6. Computer Operators. As the physics course was being encoded by the CAI coders, a computer operator had to be available for supervision and normal back-up operations on the computer. The primary contribution of the computer operator was in terms of solving linkage failures within the CAI courses. These linkage failures are computer errors which drop required indices that correctly link up various branched parts of a CAI course. In addition, the computer operators kept a very extensive set of records as to the nature of the CAI operation and scheduled work loads, so that appropriate materials were available for all students.

7. Computer Systems Programmers. In the process of developing the course, it was necessary to employ a computer systems programmer who developed the FSU Data Analysis and Management System. In addition to designing overall systems for CAI operations (e.g., more effective ways of encoding materials for data analysis, or more effective reports for authors and investigators), the computer systems programmer focused on the logistics of the total computing system. Resolving certain logistics problem, such as the requirement for extensive course listing, etc., has been very important within the CAI context in order to insure prompt processing of all requests. Moreover, the systems programmer has developed special Coursewriter functions that allow an author to gain the kinds of information and branching flow desired within the instructional sequence. Thus, the overall computer system was vastly improved by the computer systems programmer.

8. Data Analysis Programmer. Repeated data analyses, especially in terms of item frames, was required as a critical part of the project. This function typically involved taking data from the CAI data management system and processing it on any of the computers on the FSU campus. While many of these statistical programs such as items analysis and linear regression were available, the preparation of new input/output statements were a special requirement for the project.

9. CAI Proctors. As mentioned in the description of the field study, a proctor is necessary to supervise the actual mechanics of CAI instruction. The primary activity in the physics project was assisting students in preparing various media devices for actual utilization. Proctors had competencies in physics so that they could assist students with conceptual problems. However, these problem-sovling requests were so infrequent as to be almost non-occurring. In addition, the proctors kept extensive observational notes and performed interviews which provided a great deal of information related to the student's adaptation to the multi-media CAI physics course.

10. Graduate Students. Within any large CAI curriculum development project there should be an array of graduate students who can provide at least two significant contributions. First, the graduate students represent excellent back-up personnel and superior problem-solvers. The physics project was inundated with a multitude of small problems and our graduate students learned a great deal by resolving them. More importantly, though, the graduate students continually raised questions about the overall systems approach and generated small research experiments related to major questions revolving around instructional strategy and media selection.

This small-scale experimental research performed on other content topics provided important information during the formative stage of this project. Thus, it is felt that the support and active involvement of graduate students is an important ingredient in the overall mix of functional roles in a complex CAI project.

DATA ANALYSIS AND DATA MANAGEMENT. As a result of the need for data analysis in the CAI physics project, a general file structure system was developed that allowed for the organization of each student's behavioral responses into a clearly identifiable file array. This general file structure is an exceedingly important feature in data analysis for a number of reasons. First, authors tend to be primarily interested in item or frame statistics. The file structure must be manipulatable so that item and frame statistics can be printed out in a number of ways in order to characterize performance and allow for easy inference making in the revision process. As a corollary, the quick availability of this information for the authors is exceedingly important. Secondly, the file structure must be amenable to comparative analysis for various portions of the course, or various media presentations. These comparative analyses permitted the project team to decide whether certain hypotheses were in fact valid and worthy of further pursuit.

In terms of more sophisticated analyses, a number of factorial and linear regression techniques were utilized in order to obtain both with and across group comparisons. The data file structure was organized in a matrix fashion in order to generate variance and covariance matrices which could be utilized within these regression models. These linear regression analysis techniques are extremely useful in gaining insights

into the identification of variables which are important in terms of positively influencing the performance levels resulting from the instruction.

One of the great potentials of CAI data is the sequential tagging of each student's response. The sequential analysis of responses has proven to be of considerable difficulty and the FSU CAI Center is still developing programs to allow for more adequate analysis of sequential responses as well as latencies. Ultimately, it is hoped that these analyses will eventuate into quantitative models that characterize the learning process. Unfortunately, the complexities of the analysis have prevented this avenue from being pushed much beyond the linear regression models. Thus, it is felt that the investment in and development of the Data Analysis and Management System was an important ingredient for the successful completion of this project.

SUMMARY. This paper has primarily described the CAI curriculum activities of the FSU Physics Project. Unfortunately, there are few empirical reports from other CAI curriculum projects in the United States that describe their developmental procedures. Informal discussion and communications with these other CAI projects indicate close similiarities to our efforts at FSU. In light of these similiarities, the following eight factors seem critically important in determining the rate of development and success of a computer-based curriculum project:

1. The use of the systems approach and the clarity of the behavioral objectives derived for the CAI curriculum will determine the rate with which a project will be developed.

2. The variety and frequency with which varying response modalities such as speech, light pen, keyboard, etc., are required in a course can affect the rate at which a CAI curriculum can be implemented.

3. Terminal criterion performance levels for the CAI course will determine both the instructional sequence as well as the complexity of the instructional strategy. In turn, the complexity of the instructional strategy will determine the developmental rate of the project.

4. The variety of multi-media utilized in the CAI course will determine the implementation rate and the logistic ease of the instructional process.

5. The number of revision cycles required to develop an "optimal version" of a CAI course remains an unanswered question. However, the use of CAI problem sets to determine baseline performance and video recordings of excellent instruction in a conventional setting allowed for restricting the number of revision cycles.

6. The degree of sophistication of the CAI operating system is highly critical in determining the rate of development. The availability of an efficient coding language with macro techniques plus an operative computer data analysis and management system is highly essential for a favorable rate of development.

7. The number of experimental versions of the CAI course will determine the rate with which the project successfully reaches closure. However, investigation of experimental issues is necessary for the full evaluation and validation of the curriculum.

8. Since it is recognized that CAI curriculum development is a highly complex process, the use of multiple role differentiation techniques and specific functional assignments for staff members leads to more effective and efficient rates of development.

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13. ABSTRACT

The nature of developmental processes within CAI is introduced by a consideration of a learning model for adaptive instruction. The distinction betweeen instructional processes and curriculum developmental processes are elaborated in terms of instructional strategies. The nature of the instructional strategies as well as a "systems approach" model for CAI curriculum development are documented by the empirical experience at Florida State University. Ten significant professional roles required for a multi-media CAI curriculum developmental project are presented. The paper concludes with summary propositions concerning the problems and their solutions in curriculum development within the CAI world.

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